

faces (25) surrounding the structure and a plane generally parallel to said lower face defining a reference plane;

means passing vertical light from said active region out-of said lamp;

at least one metal conductor on said semiconductor structure electrically connected with said upper semiconductor layer;

a plurality of cavities in said semiconductor structure, each cavity extending from said upper face into said semiconductor structure and each containing a metal part that is in electrical contact with said lower semiconductor layer and that is distant from said outer side faces; said semiconductor structure being arranged to have several light-extraction surfaces for enhancing release of light from the semiconductor structure, said light-extraction surfaces being distant from said outer side faces and inclined to said reference plane, LED light propagating in the semiconductor structure being diverted at said light-extraction surfaces; and

electrical interconnection for causing the metal parts in said cavities to pass current together when the lamp is turned on.

39. An LED lamp according to claim 38 wherein side walls of said cavities provide at least some of said light-extraction surfaces.

40. An LED lamp according to claim 38 wherein said light-extraction surfaces are side walls of trenches.

41. An LED lamp according to claim 38 including a conductor layer in electrical contact with said upper semiconductor layer, the

conductor layer reducing voltage drops in the upper semiconductor layer.

42. An LED lamp according to claim 41 wherein said conductor layer is of metal.

43. An LED lamp according to claim 38 including a substrate that is light-passing to visible light and over which at least one of said semiconductor layers has been grown.

44. An LED lamp according to claim 42 wherein said conductor layer is light-passing by being thin.

45. An LED lamp according to claim 38 wherein said metal parts serve as reflectors for light generated by said active region.

46. An LED lamp according to claim 38 wherein said light-extraction surfaces are oblique to said reference plane.

47. An LED lamp according to claim 38 wherein there are islands of said upper face defined by said light-extraction surfaces.

48. An LED lamp according to claim 38 including amorphous material at said light-extraction surfaces.

49. An LED lamp according to claim 38 wherein there are cavities that cut through said semiconductor structure.

50. An LED lamp according to claim 38 wherein each of said light-extraction surfaces meets an associated portion of said upper face at an angle measured through semiconductor of at least 90 degrees.

51. An LED lamp according to claim 38 including meandering conductors on said semiconductor structure.

52. An LED lamp according to claim 38 including a heat sink less than 50 microns away from said active region.

53. An LED lamp for generating incoherent visible light, comprising:

Fig 53
an inorganic semiconductor structure comprising a lower semiconductor layer and an upper semiconductor layer, said lower and upper semiconductor layers forming a diode and an active region between said layers generating light, said structure having outer side faces surrounding the structure;

LED portions within said semiconductor structure, each LED portion provided with an associated conductor for energizing the portion and an associated electrical link (71) in series with the associated conductor, some of said LED portions being faulty and having their associated links deliberately disrupted;

electrical connections for energizing several of said LED portions together; and

wherein said semiconductor structure has light-extraction surfaces arranged for harvesting light from said semiconductor structure, said light-extraction surfaces being distributed distant from said outer side faces and being inclined to said active region, light generated in the semiconductor structure being diverted at said light-extraction surfaces.

54. An LED lamp according to claim 53 wherein said disrupted links are disrupted fuses.

55. An LED lamp according to claim 53 wherein said disrupted links are on said semiconductor structure.

56. An LED lamp for generating incoherent visible light, comprising:

an inorganic semiconductor structure comprising: a lower semiconductor layer having a lower face thereof; an upper semiconductor layer grown over said lower semiconductor layer and having an upper face thereof, said lower and upper semiconductor layers forming a diode; and an active region between said layers generating light a substantial proportion of which propagates parallel to said active region guided by internal reflections at said upper and lower faces, said structure having outer side faces surrounding the structure;

a conductor layer covering and in electrical contact with said upper semiconductor layer;

a plurality of meandering tracks on said lower semiconductor layer at least one of which has a portion thereof positioned between light generating parts of said semiconductor structure,

wherein said semiconductor structure is arranged to have several light-extraction surfaces for release of said guided light from the semiconductor structure, said light-extraction surfaces being distant from said outer side faces and inclined to said active region.

57. An LED lamp according to claim 56 wherein at least one of said tracks comprises a conductor finger.

58. An LED lamp according to claim 56 including amorphous translucent material at said light-extraction surfaces.

59. An LED lamp according to claim 56 wherein said upper face is within 10 microns of said lower face.

60. An LED lamp for generating incoherent visible light, comprising:

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an inorganic semiconductor structure comprising: a lower semiconductor layer having a lower face thereof; an upper semiconductor layer grown over said lower semiconductor layer and having an upper face thereof, said lower and upper semiconductor layers forming a diode; and an active region between said layers generating light a substantial proportion of which propagates parallel to said active region guided by internal reflections at said upper and lower faces, said structure having outer side faces surrounding the structure;

a layer of material translucent to visible light and of lower refractive index than said lower semiconductor layer below the lower semiconductor layer, the translucent layer acting as a reflector for said guided light;

a semiconductor substrate of higher refractive index than said layer of translucent material below the layer of translucent material, the substrate passing vertical light from said active region;

a conductor layer covering and in electrical contact with said upper semiconductor layer;

a plurality of spaced-apart opaque conductors on said semiconductor structure for energizing one of said upper and lower semiconductor layers, at least one of the opaque conductors appearing between light-generating portions of said semiconductor structure as viewed normal to said reference plane;

electrical connection causing said opaque conductors to pass current to said semiconductor structure together when the lamp is turned on; and

wherein vertical light from said active region passes between a pair of said opaque conductors and wherein said semiconductor structure is arranged to have several light extraction surfaces for release of said guided light from the semiconductor structure, said light-extraction surfaces being distant from said outer side faces and inclined to said reference plane for diverting said guided light for output from the semiconductor structure.

61. An LED lamp according to claim 60 wherein said conductor layer is light-passing.

62. An LED lamp according to claim 60 including amorphous material at said light-extraction surfaces.

63. An LED lamp according to claim 60 wherein said light extraction surfaces are side walls of cavities that extend into said lower semiconductor layer.

64. An LED lamp for generating incoherent visible light, comprising:

an inorganic semiconductor structure comprising a lower semiconductor layer and an upper semiconductor layer, said lower and upper semiconductor layers forming a diode and an active region between said layers generating light, said structure having outer side faces surrounding the structure;

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LED portions within said semiconductor structure each having an anode and a cathode, the cathode of one of the portions being metallurgically connected to the anode of another of the LED portions;

electrical connections for energizing several of said LED portions together; and

wherein said semiconductor structure has light-extraction surfaces arranged for harvesting light from said semiconductor structure, said light-extraction surfaces being distributed distant from said outer side faces and being inclined to said active region, light generated in the semiconductor structure being diverted at said light-extraction surfaces.

65. An LED lamp according to claim 64 including a first set of said LED portions electrically connected in parallel; a second set of said LED portions electrically connected in parallel; and electrical connection for driving said sets in series.

66. An inorganic semiconductor structure comprising a lower semiconductor layer and an upper semiconductor layer, said lower

and upper semiconductor layers forming a diode and an active region between said layers generating light, said structure having outer side faces surrounding the structure;

at least one first conductor in electrical contact with said lower semiconductor layer;

at least one second conductor in electrical contact with said upper semiconductor layer, part of the second conductor crossing over said first conductor and being insulated from the first conductor by dielectric material; and

wherein said semiconductor structure has light-extraction surfaces arranged for harvesting light from said semiconductor structure, said light-extraction surfaces being distant from said outer side faces and being inclined to said active region, light generated in the semiconductor structure being diverted at said light-extraction surfaces.

67. An LED lamp according to claim 66 including a conductor layer in electrical contact with said upper semiconductor layer.

68. An inorganic semiconductor structure comprising a lower semiconductor layer and an upper semiconductor layer grown over said lower semiconductor layer, said lower and upper semiconductor layers forming a diode and an active region between said layers generating light, said structure having outer side faces surrounding the structure;

a plurality of U-shaped conductors in electrical contact with said lower semiconductor layer, the U-shaped conductors being metallurgically interconnected with each other; and

wherein said semiconductor structure has light-extraction surfaces arranged for harvesting light from said semiconductor structure, said light-extraction surfaces being distant from said outer side faces and being inclined to said active region, light generated in the semiconductor structure being diverted at said light-extraction surfaces.

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69. An LED lamp according to claim 68 including a conductor layer in electrical contact with said upper semiconductor layer.

70. An LED lamp for generating incoherent visible light, comprising:

an inorganic semiconductor structure comprising: a lower semiconductor layer having a lower face thereof and an upper semiconductor layer having an upper face thereof, said lower and upper semiconductor layers forming a diode and an active region between said layers generating light, said structure having surrounding outer side faces;

means harvesting vertical light from said active region for output of that light from the lamp;

a heat sink above said upper face for cooling said active region;
and

wherein said semiconductor structure has several light diverting surfaces distant from said outer side faces and each meeting said upper face at an obtuse angle measured through semiconductor; each of the light-diverting surfaces having an associated metallic reflector thereat at least part of which is electrically substantially insulated from the light-diverting surface.

71. An LED lamp according to claim 70 including a reflector above said upper face for reflecting back into said upper layer upward light from said active region.

72. An LED lamp according to claim 71 including a thin dielectric layer between said upper face and said reflector.

73. An LED lamp according to claim 70 wherein said upper face is within 10 microns of said lower face.

74. An LED lamp according to claim 70 wherein said upper semiconductor layer is grown over said lower semiconductor layer.

75. An LED lamp for generating incoherent visible light, comprising:

an inorganic semiconductor structure comprising: a lower semiconductor layer having a lower face thereof; an upper semiconductor layer having an upper face thereof, said lower and upper semiconductor layers forming a diode; and an active region between said layers generating light, a plane generally parallel to said lower face defining a reference plane; means harvesting vertical light from said active region;

a plurality of opaque conductor parts in electrical contact with said upper semiconductor layer;

a plurality of light-extraction grooves provided in said semiconductor structure each having first and second opposite side walls, the first side wall being light passing and oblique to said reference plane and the second side wall comprising a metallic reflector arranged for reflecting light passing through the first side wall; and

electrical connection for causing currents to be fed to said upper semiconductor layer via said opaque conductor parts when the lamp is turned on.

76. An LED lamp according to claim 75 including a reflector below said lower face receiving light reflected by one or more of said first side walls.

77. An LED lamp for generating incoherent visible light, comprising:

an inorganic semiconductor structure comprising: a lower semiconductor layer having a lower face thereof; an upper semiconductor layer having an upper face thereof, said lower and upper semiconductor layers forming a diode; and an active region between said layers generating light, a plane generally parallel to said lower face defining a reference plane; means harvesting vertical light from said active region;

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a plurality of opaque conductor parts in electrical contact with said upper semiconductor layer and between which light passes; a plurality of light-extraction grooves provided in said semiconductor structure each having first and second opposite side walls, the first side wall being light-passing and the second side wall comprising a metallic reflector arranged for reflecting light passing through the first side wall, said metallic reflector being part of a concave metallic reflector that reflects some light rays from the light-passing wall at least twice successively; and

electrical connection for causing currents to be fed to said upper semiconductor layer via said opaque conductor parts when the lamp is turned on.

78. An LED lamp for generating incoherent visible light, comprising:

an inorganic semiconductor structure comprising: a lower semiconductor layer having a lower face thereof; an upper semiconductor layer having an upper face thereof, said lower and upper semiconductor layers forming a diode; and an active region between said layers generating light; means harvesting vertical light from said active region;

a plurality of opaque conductor parts in electrical contact with said upper semiconductor layer and between which light passes; a plurality of light-extraction grooves excavated in said semiconductor structure each having first and second opposite side

walls, the first side wall being light passing and the second side wall comprising a metallic reflector arranged for reflecting light passing through the first side wall; and

electrical connection for causing currents to be fed to said upper semiconductor layer via said opaque conductor parts when the lamp is turned on.

79. An LED lamp according to claim 78 including a light - passing conductor layer in electrical contact with said upper face.

80. An LED lamp according to claim 78 including a light - passing substrate under said semiconductor structure and a reflector under said substrate redirecting downward light generated by said active region.

81. An LED lamp for generating incoherent visible light, comprising:

an inorganic semiconductor structure comprising: a lower semiconductor layer having a lower face thereof; an upper semiconductor layer having an upper face thereof, said lower and upper semiconductor layers forming a diode; and an active region between said layers generating light;

means harvesting vertical light from said active region;
a plurality of opaque conductor parts in electrical contact with said upper semiconductor layer and between which light from said active region passes;

a plurality of light-extracting trenches in said semiconductor structure, at least one of the trenches being inclined to another of the trenches by an acute angle; and

electrical connection for causing currents to be fed to said upper semiconductor layer via said opaque conductor parts when the lamp is turned on.

82. An LED lamp according to claim 81 wherein said trenches form triangular areas in said upper face.

83. An LED lamp according to claim 81 including a light - passing conductor layer in electrical contact with said upper face.

84. An LED lamp for generating incoherent visible light, comprising: an inorganic semiconductor structure comprising: a lower semiconductor layer having a lower face thereof and an upper semiconductor layer having an upper face thereof, said lower and upper semiconductor layers forming a diode; and an active region between said layers generating light, said structure having outer side faces surrounding the structure; means harvesting vertical light from said active region;

a plurality of spaced-apart opaque conductors each in electrical contact with said lower semiconductor layer, at least one of the opaque conductors appearing between light generating portions of said structure as viewed normal to said active region,

a heat sink above said upper semiconductor layer for cooling said active region;

electrical connection for causing currents to be fed to said lower semiconductor layer via said opaque conductors when the lamp is turned on;

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a metallic reflector at and covering said upper face for harvesting upward vertical light from said active region; and wherein said semiconductor structure is formed to have light-diverting surfaces each meeting said upper face at an obtuse angle measured through semiconductor, each of the light diverting surfaces being distant from said outer side faces and reflecting light generated by an associated portion of said active region, a plane normal to said reference plane cutting a plurality of pairs of said light-diverting surfaces.

85. An LED lamp according to claim 84 wherein a said pair of reflective surfaces are separated by a space devoid of semiconductor.

86. An LED lamp according to claim 84 including a thin light passing dielectric layer between said upper face and said metallic reflector.

87. An LED lamp according to claim 84 wherein said metallic reflector is provided by said heat sink.

88. An LED lamp according to claim 84 including reflectors parallel to said light-diverting surfaces and comprising metal.

89. An LED lamp according to claim 84 wherein said upper face is covered with a conductor layer that is in electrical contact with the upper semiconductor layer.

90. An LED lamp according to claim 84 wherein said upper face is divided into islands by said light-diverting surfaces.

91. An LED lamp according to claim 84 wherein said light-extraction surfaces each cut said lower semiconductor layer.

92. An LED lamp for generating incoherent visible light, comprising:

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an inorganic semiconductor structure comprising: a lower semiconductor layer having a substantially flat lower face thereof; an upper semiconductor layer grown over said lower semiconductor layer and having a substantially flat upper face thereof, said lower and upper semiconductor layers forming a diode; and an active region between said layers generating light a substantial proportion of which propagates parallel to said active region guided by internal reflections at said upper and lower faces, said structure having outer side faces surrounding the structure;

a conductor layer covering and in electrical contact with said upper semiconductor layer;

at least one metal conductor electrically connected with said lower semiconductor layer;

means harvesting vertical light from said active region; and wherein said semiconductor structure is arranged to have several distributed light-extraction surfaces for release of said guided light from the semiconductor structure, said light extraction surfaces being

distant from said outer side faces, interfacing with a translucent non-semiconductor medium, and inclined to said upper face.

93. An LED lamp according to claim 92 wherein said light-extraction surfaces each cut into both of said lower and upper semiconductor layers.

94. An LED lamp according to claim 92 wherein said conductor layer is of metal.

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95. An LED lamp according to claim 94 wherein said conductor layer of metal is light-passing.

96. An LED lamp according to claim 92 including a layer of material translucent to visible light and of lower refractive index than said lower semiconductor layer under the lower semiconductor layer, and including a semiconductor substrate of higher refractive index than said layer of translucent material below the layer of translucent material.

97. An LED lamp according to claim 92 wherein said light-extraction surfaces are oblique to said upper face.

98. An LED lamp according to claim 92 including a non-semiconductor substrate that is translucent to visible light and over which said semiconductor structure is grown.

99. An LED lamp according to any of claims 38, 53, 56, 64, 66, 68, 70, 75, 84 or 92 including a sapphire substrate on which said semiconductor structure is grown.

100. An LED lamp for generating incoherent visible light, comprising:

et al
an inorganic semiconductor structure comprising: a lower semiconductor layer having a lower face thereof; an upper semiconductor layer grown over said lower semiconductor layer and having an upper face thereof, said lower and upper semiconductor layers forming a diode; and an active region between said layers generating light a substantial proportion of which propagates parallel to said active region guided by internal reflections at said upper and lower faces, said structure having outer side faces surrounding the structure;

a conductor layer covering and in electrical contact with said upper semiconductor layer;

at least one metal conductor electrically connected with said lower semiconductor layer;

means harvesting vertical light from said active region; and wherein said semiconductor structure has a plurality of cavities distant from said outer side faces, each extending from said upper face and each terminating at a floor that is above said lower face and below said active region, side walls of the cavities diverting said guided light.

101. An LED lamp according to claim 100 wherein said side walls are oblique to said lower face, whereby release of guided light ~~is enhanced.~~

102. An LED lamp according to claim 100 wherein said side walls are sides of separate LEDs that are driven together.

103. An LED lamp according to claim 100 wherein said lower semiconductor layer comprises a sub-layer of low resistivity.

104. An LED lamp according to claim 100 wherein said side walls pass light.

105. An LED lamp according to claim 100 including: a first conductor on said semiconductor structure; a second conductor on said semiconductor structure crossing over said first conductor; and insulation preventing electrical contact between the first and second conductors.

106. An LED lamp according to claim 100 wherein each of said cavities contains a metal floor-conductor on the cavity floor, each floor-conductor feeding current to portions of said semiconductor structure that are on opposite sides of the floor conductor and the floor-conductors in the cavities feeding current to said lower semiconductor layer together when the lamp is turned on.

107. An LED lamp according to claim 100 wherein said semiconductor structure includes a plurality of LEDs the tops of which are electrically joined together by an opaque conductor.--

REMARKS

By this Supplemental Preliminary Amendment claims 1-18 have been replaced by new claims 38-107. Entry is requested. The additional claims fee of \$1,184.00 (\$504 excess independent claims;